Technology-Enabled Content in Engineering Science Curriculum

Eugene Rutz, Virginia Elkins, Joyce Pittman, Max Rabiee, and Richard Miller
University of Cincinnati

Abstract
Engineering technology technical courses often have both lecture and accompanying laboratory sessions. The laboratory assignments reinforce the understanding of the topics studied during the lecture sessions. A planning grant was awarded from the National Science Foundation through their Bridges for Engineering Education Program to develop technology-enabled content in engineering science courses. Content was developed to appeal to a variety of learning styles and to support student-centered learning. This paper will describe the content development and delivery and discuss the impact it had on engineering technology education.

Course / Content Development
Content was developed to support a course in Flexible Automation offered in the College of Applied Science. The content was developed collaboratively among educational technology experts in the College of Engineering, faculty from the College of Applied Science, and experts in instructional design in the College of Education. The project sought to develop content that would appeal to a variety of student learning styles and thus better engage the students in the learning process[1]. The various modes of instruction developed during the project were categorized as:

- Read It – text and illustrations to appeal to visual learners / linguistic learners
- Watch It – streaming media presentation to appeal to visual learners / auditory learners
- Visualize It – animations to appeal to spatial learners / visual learners
- Try It – active exercises to appeal to kinesthetic learners / active learners

Guidelines based on models of best practice[2,3] were established for content creation to ensure instructional design appropriate for technology-mediated education was used. These guidelines were developed by the collaborators from the College of Education and the participating faculty. Each of the instructional modalities listed above had an associated content development guideline. These guidelines are shown in Figures 1 - 4.

With these guidelines in place, material was developed by graduate assistants working with faculty, instructional designers, and the project manager. The new materials were developed to be a supplement and / or extension of the "traditional" materials and to be delivered via the web or CD-Rom. Animations and active exercises were derived from materials presented in the textbooks to be consistent with that resource. Streaming media presentations and web-based text and graphics were derived from both the course text and other standard texts to provide a richer educational resource.

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Technology-Enabled Engineering Science Content

"Try It" Content Development Guidelines

This module allows students to interact with the content to the greatest degree possible. It is intended to support active learning and student inquiry.

Module contains:
1. Description of the content of the section and a procedure for using the module
2. Physical model and a graphic representation
3. Interactive exercise that allows students to manipulate variables and see the outcomes of this manipulation
4. Discussion of what happens for each interaction
5. Discussion of the underlying principles

Description
A brief summary of the topic covered (e.g. stress), a cross reference to the section in the textbook, and an explanation of how the module works. This explanation should provide clear instructions on how parameters are manipulated and how the student receives feedback. The explanation should also inform students of any options they have and how to get help if they need it.

Models
To provide a real world context, the module should first introduce a familiar concept or situation for which the topic is applicable (e.g., a bridge). A graphical representation such as a free body diagram should then be shown.

Interactive Exercise
Students are able to change various aspects of the model and see the results of these manipulations. Clarity is very important – there must be an understandable connection between cause and effect.

What Happened
An explanation of the cause and effect should be given (e.g., increasing the load on the bridge caused the stress to increase).

Underlying Principles
The cause and effect discussed above should be related to the underlying principles being presented. This will typically be an explanation of the governing equations and which variables in the equations were involved in the manipulations.

Figure 1 "Try It" Content Development Guidelines

Technology-Enabled Engineering Science Content

"Read It" Content Development Guidelines

This module provides a text and graphics mode of content presentation. This module allows students to move through the content according to their interests. It is intended to support visual and active learning.

Module contains:
1. Description of the content of the section and a procedure for using the module
2. "Big picture" view of concepts
3. Underlying theory behind concepts
4. Equations used to describe relation of real world to theory
5. Application of the concept
6. Hyperlinks that connect big picture to theory to equations to applications
7. Resources for extending the learning experience

Description
A brief summary of the topic covered (e.g. stress), a cross reference to the section in the textbook, and an explanation of how the module works. This explanation should provide clear instructions on how the material is laid out and how students can progress through the material. The explanation should also inform students of any options they have and how to get help if they need it.

Big Picture
This section provides a pragmatic context for the material being presented. It enables students to see the relevance of the topic and illustrates real-world examples that are common to all. Images of familiar items (e.g., bridges) should be provided along with text that describes why the concepts being discussed are important for that item. Links should be provided to the Theory section, the Governing Equations section and the Applications section.

Theory
This section describes the theory behind the concept being presented. It provides the scientific principles students need to know to properly apply the concepts. Links should be provided to the Big Picture section, the Governing Equations section and the Applications section. Links to additional resources are also provided.

Governing Equations
This section presents the equations that link the theory to the physical reality. Each parameter is described and typical uses of the equations described. Links should be provided to the Theory section, the Theory section and the Applications section.

Applications
This section provides examples of how the concepts are used in engineering analysis. A real-world situation is described and the correlation to this and the governing equations is developed.
Links should be provided to the Theory section, the Governing Equations section and the Big Picture section. Links to other resources are also provided.

Figure 2 "Read It" Content Development Guidelines

Technology-Enabled Engineering Science Content

"Visualize It" Content Development Guidelines

This module allows students to understand the relationships between real world concepts / situations and engineering representation of those concepts. It is intended to support visual learning.

Module contains:

8. Description of the content of the section and a procedure for using the module
9. Physical model and a graphic representation
10. Animation that illustrates the connection between the physical model and the governing equations

Description
A brief summary of the topic covered (e.g. stress), a cross reference to the section in the textbook, and an explanation of how the module works. This explanation should provide clear instructions on how to view the animation and inform students of any options they have (pausing, "rewinding") as well as how to get help if they need it.

Models
To provide a real world context, the module should first introduce a familiar concept or situation for which the topic is applicable (e.g., a bridge). A graphical representation such as a free body diagram should then be shown.

Animation
Students need to be shown the connection between the underlying concepts and equations and the physical, real world examples. Clarity is very important; a specific, limited amount of information should be presented. An explanation of the parameters in an equation to characteristics of the physical model must be made.

Figure 3 "Visualize It" Content Development Guidelines

The content developed during this project was provided as supplemental materials to students in traditional courses. Students were not required to use the material but they were encouraged on multiple occasions to make use of the materials to help learn the concepts. Moreover, the technology-enabled content was always available to the students via the Blackboard course management system and/or a CD.

Technology-Enabled Engineering Science Content

"Watch It" Content Development Guidelines

This module provides a traditional delivery mode using technology to allow students to receive instruction at their convenience. This module presents the content in a style that is very familiar to students yet which puts them in control of pace and setting.

Module contains:

11. Description of the content of the section and a procedure for using the module
12. Streaming audio and video lecture

Description

A brief summary of the topic covered (e.g. stress), a cross reference to the section in the textbook, and an explanation of how the module works. This explanation should provide clear instructions on how parameters are manipulated and how the student receives feedback. The explanation should also inform students of any options they have and how to get help if they need it.

Streaming Media

Lectures are taped and digitized to provide content at the students' convenience. The presentation includes audio and video synchronized with a PowerPoint presentation.

Figure 4 "Watch It" Content Development Guidelines

Examples of the various types of content are illustrated below. Figure 5 is an illustration of the "Watch It" streaming media presentation. Figure 6 is an illustration of the "Try It" interactive exercise. Figures 7and 8 are illustrations of the "Visualize It' animations.

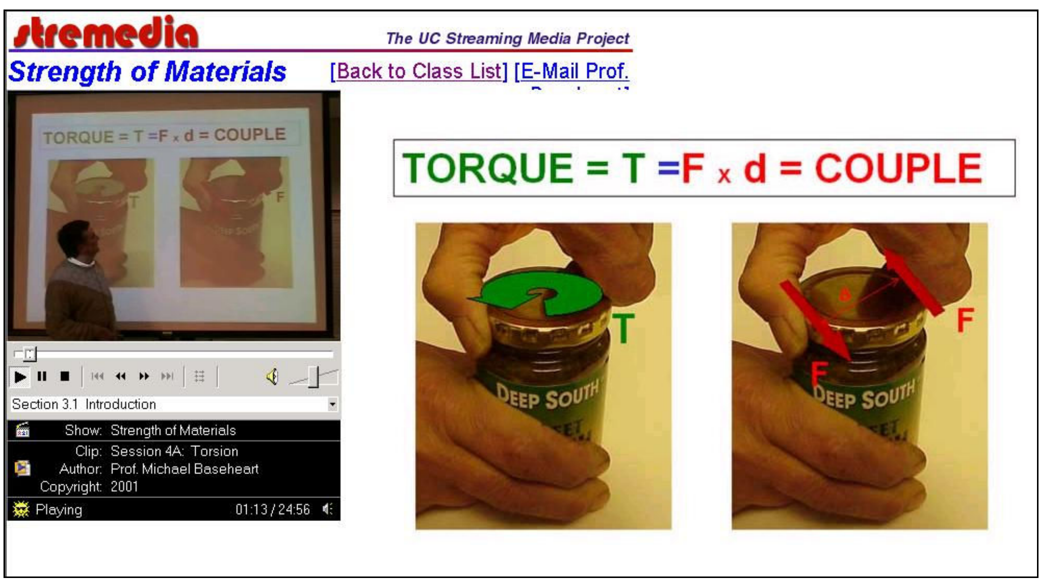

Figure 5 "Watch It" - Streaming Media Example

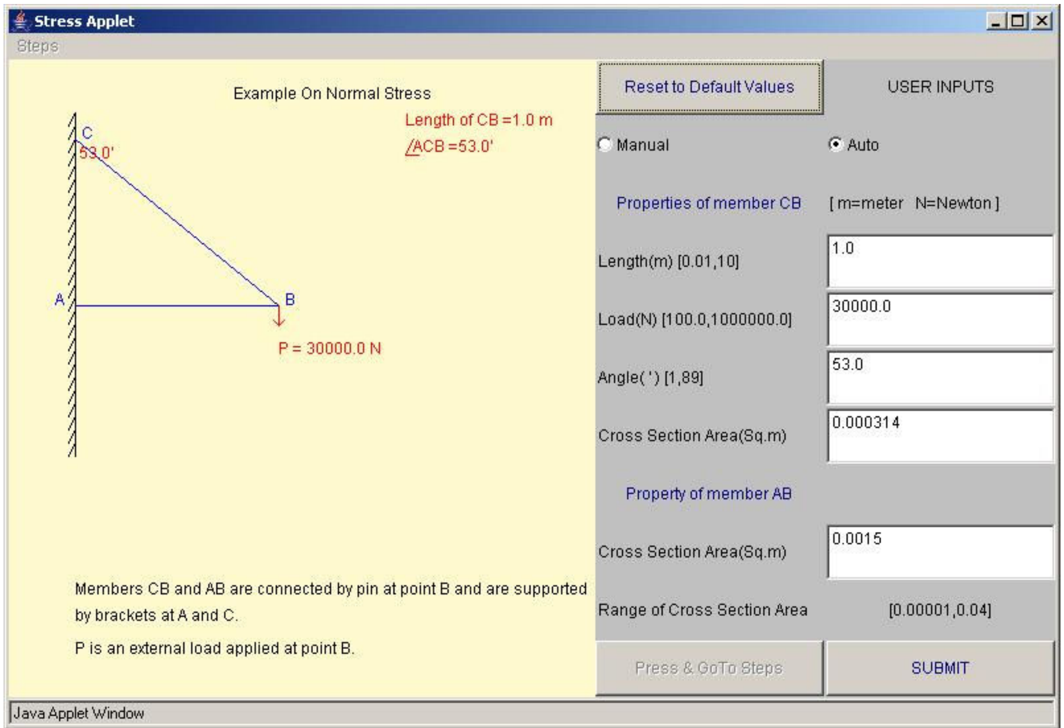

Figure 6 "Try It" - Interactive Exercise Example

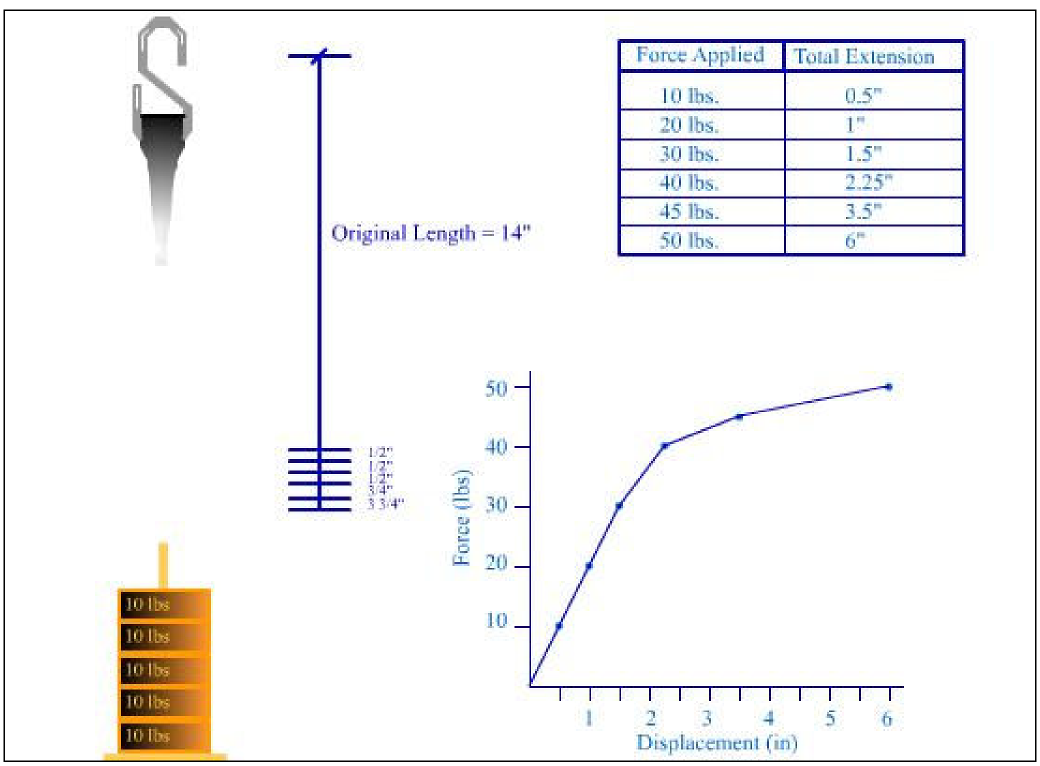

Figure 7 "Visualize It" – Animation Example

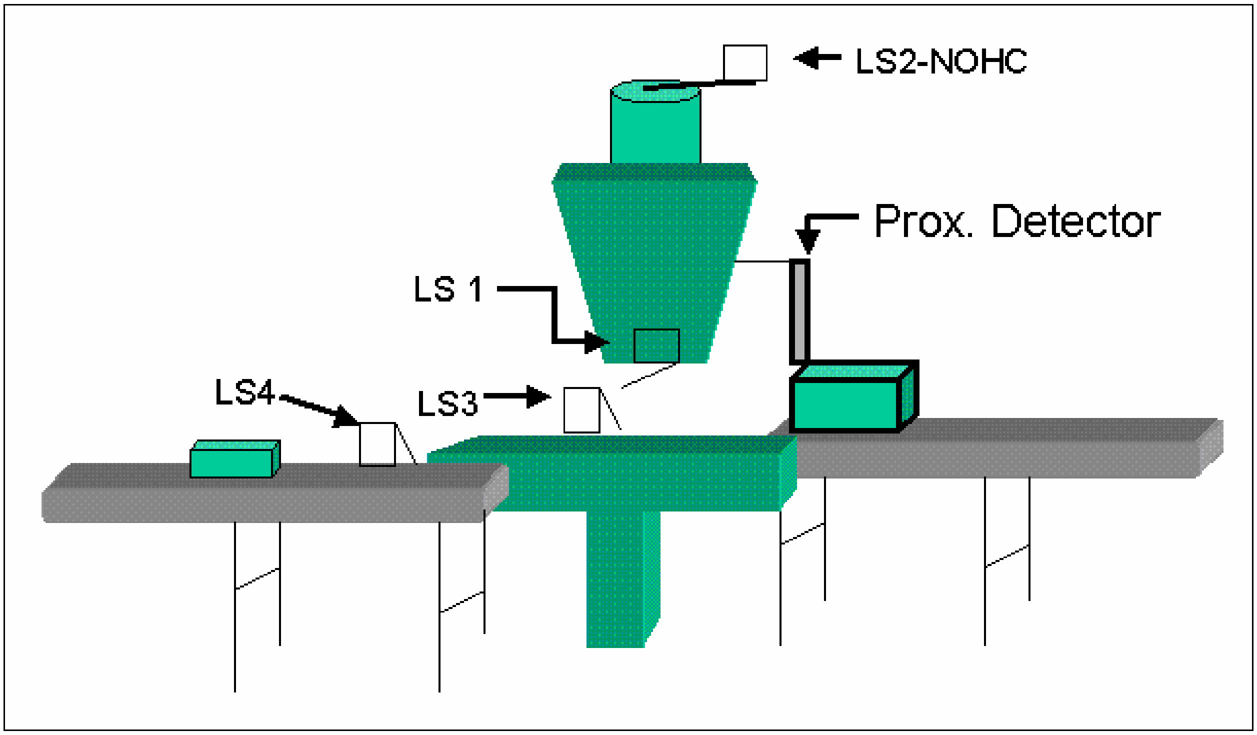

Figure 8 "Visualize It" – Second Animation Example

Course Delivery

The course was taught in a traditional lecture / laboratory format with the technology-enabled content available as supplemental learning material. The University of Cincinnati uses the Blackboard course management system to facilitate use of instructional technology and to provide communication and collaboration. Figure 9 illustrates the content available to the students through the Blackboard system.

Since this particular course is taken by traditional students and working adults, students participating in the course attended a traditional lecture / laboratory presentation one evening per week. Students were informed regarding the availability of the technology-enabled content and instructed on how the content could help them with the course. Since this new content was designed to supplement the traditional materials / lecture, its use was not mandatory. However, students were encouraged multiple times during the term to take advantage of this resource.

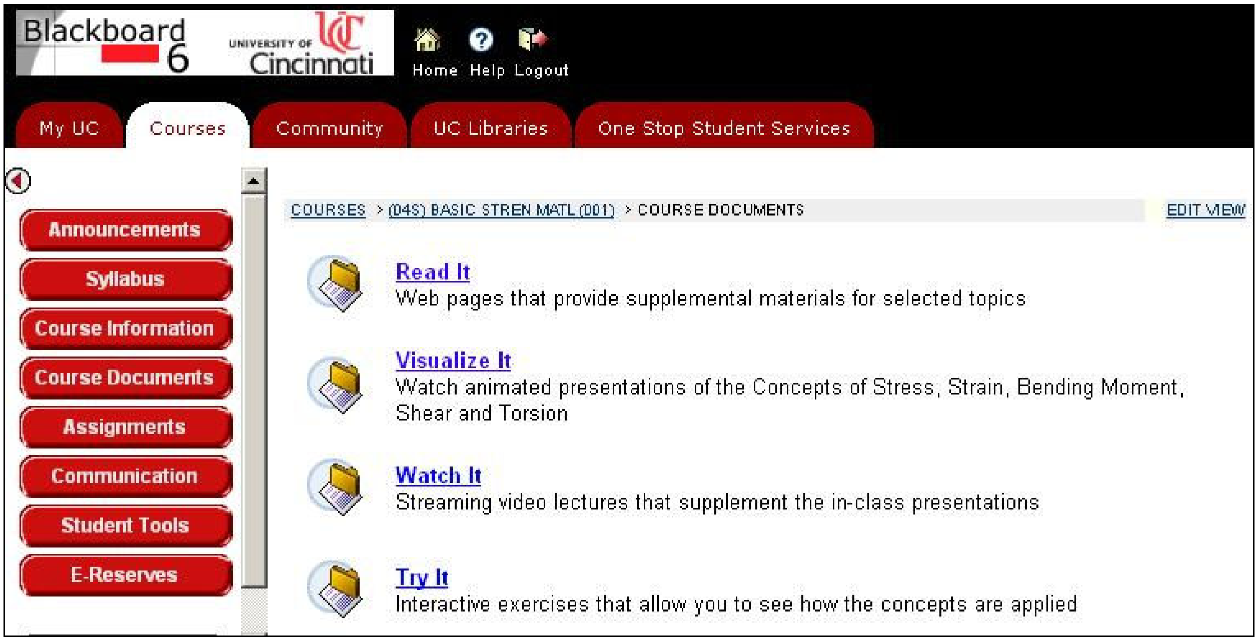

Figure 9 Content Presented through Blackboard Course Management System

Evaluation

For this pilot grant, it was not feasible to quantitatively assess improvement in test or class grades based on the use of the technology-enabled content. There are a number of assessments that were made however. Table 1 lists the grades for the Flexible Automation course during the project period (Spring '04) and the year before when the same course was taught by the same instructor.

Table 1 Average Grades for Flexible Automation Course

Term	# of Students	Exam 1	Exam 2	Exam 3	Course Grade
Spring '04	20	95.1	89.8	82.5	89.2
Spring '03	20	87.3	92.6	79.9	86.8

A qualitative evaluation of course grades indicates that students did at least as well in the course when the technology-enabled content was available. This is consistent with other studies[1]. Given the small numbers of students and the exploratory nature of this study, we did not quantitatively determine whether there was a statistically significant difference in students' grades for this project.

The project sought to provide materials that would appeal to a variety of learning styles and thus better engage the students in the course content. Student evaluations of the efficacy of the technology-enabled content and other course related parameters were performed as a measure of student engagement. Three evaluations were administered: one toward the beginning of the term, one around mid-term and one at the completion of the term. The results are shown in Table 2. A modified Liekert scale was used with 1 indicating strongly disagree, 3 as neutral and 5 strongly agree.

Table 2 Student Evaluation of the Technology-Enabled Content

	Beginning	Mid-term	Final
The animations helped me learn the material	3.4	3.5	3.4
The web pages helped me learn the material	3.2	3.9	3.7
The streaming video helped me learn the material	3.7	4.6	4.1
The interactive exercises helped me learn the material	3.1	4.1	3.8
The material for the course is interesting and engaging	3.9	4.0	3.9
Given a choice I would enroll in a technology-enabled course	4.2	4.3	4.2
Compared with other instructors I've had, the instructor for this course was effective	4.1	4.3	4.2
I would prefer a traditional course	3.0	2.4	3.1
The technology-enabled content was a helpful addition to the course	3.7	3.9	3.8

In addition, student comments were solicited regarding the content. Table 3 lists examples of the major themes expressed in the student comments.

Table 3 Student Comments Regarding the Technology-Enabled Content

As a non-traditional student, I study very late in the evening. It is helpful to have this material at my fingertips
Web, video, animations were great
All this information may cause a decrease in attendance.
This variety of content not required for this level of course.
I prefer the videos and the exercises. I travel and can use these via the CD on the plane while I make use of my time

The project had generally positive results, though not equal for all modes of instruction. The responses given in Tables 2 & 3 indicate that students do value the technology-enabled content and were most receptive to the streaming media mode of delivery. Particularly noteworthy is the positive response to the opportunity to enroll in a technology-enabled course. The authors conclude that much of the positive response is due to the content being available to students at their convenience – a major step in providing student-centered education. Based on these student evaluations, we conclude that the project has been successful in providing content in manners that are more engaging than the traditional lecture.

Next Steps

This project has demonstrated the efficacy of technology-enabled content and provided the participants a better understanding of the pedagogy associated with instructional technology. As resources are available, we will develop materials for other courses with two specific goals in mind:

1. Provide materials that appeal to a variety of learning styles
2. Allow students to access the materials at their convenience

We will continue to evaluate student performance and engagement with the various technologies and seek to discern whether certain technologies are more effective than others. Likewise, we hop to learn through additional studies if the use of technology can enable students to learn and apply the content more fully than the traditional lecture mode of presentation.

Bibliography

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Biographical Information

EUGENE RUTZ is Director of Engineering Professional Development and Distance Learning at the University of Cincinnati. He holds a BS in Nuclear Engineering, an MS in Mechanical Engineering and a PE License from the State of Ohio. Mr. Rutz has 10 years of industry experience and 15 years of university-related experience. He has taught courses in a traditional classroom setting, using interactive video and asynchronously via the web.

VIRGINIA ELKINS is currently Academic Director for the College of Applied Science and teaches Gender Communications, Group Communication and Problem Solving, Psychology of Women and senior Capstone seminars. Dr. Elkins area of expertise is leadership and career development with special interests in gender communications and human development.

JOYCE PITTMAN earned her Ph.D. in Education from the University of Iowa. Dr. Pittman is an Assistant Professor in the College of Education, Human Services and Criminal Justice at the University of Cincinnati. Her expertise is in the areas of instructional design and instructional technology.

MAX RABIEE earned his Ph.D. in Electrical Engineering from the University of Kentucky in 1987. He is a Professor of Electrical and Computer Engineering Technology (ECET) at the University of Cincinnati. Dr. Rabiee is a registered professional engineer, and a senior member of the Institute of Electrical and Electronic Engineering (IEEE). He is also a member of the American Society of Engineering Education (ASEE), the Eta Kappa Nu Electrical Engineering Honor Society, and the Tau Beta Pi Engineering Honor Society.

RICHARD MILLER received his Ph.D. in 1989 from Northwestern University in Civil Engineering. Dr. Miller is an Associate Professor in the Department of Civil and Environmental Engineering. Dr Miller was awarded the Distinguished Educator Award for 2003 by the Precast/Prestressed Concrete Institute.